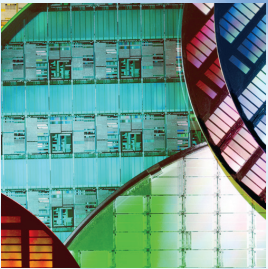
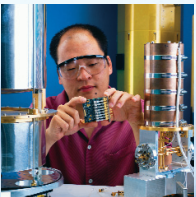


An Assessment of the United States Measurement System:
Addressing Measurement Barriers to Accelerate Innovation

In Brief





Gage blocks (standardized sets of steel blocks of accurately determined thicknesses) were among the key measurement tools that enabled the rise of mass production and interchangeable parts. Today, in industries from aerospace to biotechnology to nanoelectronics, the demand for ever more precise dimensional measurements is unceasing.

Our nation’s prosperity and security depend increasingly on technological innovation. Innovation will define the competitiveness of U.S. industry in global markets for high value-added goods and services. How well the United States performs in a growing field of challengers racing to lead in developing and commercializing new technologies will set the pace of future economic growth.

Numerous recent studies concur with this conclusion by the private sector’s Council on Competitiveness:

Innovation will be the single most important factor in determining America’s success through the 21st century.

Simply maintaining today’s level of performance will not be sufficient. Indeed, the council and others assert that accelerating innovation is critical for the United States to maintain its competitive edge in the world economy.

Picking up the pace will require continual advances in the measurement capabilities that underpin all of the many steps in the process of innovation.

Measurement Matters to Innovation

Because advanced measurement capabilities are essential to innovation in every major economic area and at every stage—from discovery to commercialization—the National Institute of Standards and Technology (NIST) initiated an assessment of the United States Measurement System (USMS). This assessment, carried out with partners from industry, academia, and government, focused specifically on measurement-related barriers to technolog-

**Sector/Technology
Areas Assessed**

Building & Construction

Chemicals

Defense & Homeland Security

Discrete-Parts Manufacturing,
Including Automotive

Electronics & IT Hardware

Energy, Power & Environment

Health Care, Including
Bioimaging

IT Software

Materials

Nanotechnology

Semiconductor Electronics

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In Focus: Four Stages of Technological Innovation

- Applied Research
- Production
- Market Placement
- End Use

ical innovation—the multi-step process concluding with the introduction of new technology into the marketplace. Whether new capabilities, improvements in measurement-related services, or other responsive actions, solutions to critical measurement needs were determined to be necessary means to an important end: innovation success.

Consider, for example, the importance of advanced measurement tools to semiconductor manufacturing, the foundational industry for the nation’s vast information technology sector. In 2006, the U.S. semiconductor industry will spend an estimated \$9 billion on measurement equipment—equivalent to the cost of building three new state-of-the-art “chip” factories.

Assuming that the entire U.S. high-technology sector invests a similar percentage of revenues in measurement, this collection of high-performing U.S. industries would have spent about \$70 billion on measurement in 2004.

An Initial Check-Up

The sampling of measurement needs identified as part of this assessment—723 measurement-related barriers to technological innovation across 11 industrial sectors and technology areas—yielded a system-wide perspective. Collectively and individually, these measurement problems are the basis for an initial appraisal of the USMS’s fitness for supporting world-class innovation performance.

In all, more than 1,000 people contributed to the USMS assessment. All measurement needs identified and USMS-related findings and conclusions reached as part of this undertaking were validated by industry representatives or technology experts or were derived from publicly available technology roadmaps and other similar reports.

Snapshot of the USMS

The USMS encompasses all private and public organizations that develop, supply, use, or ensure the validity of measurement results. The scope of the USMS includes and extends beyond what is commonly known as the national measurement system (NMS). Common to all industrialized nations and many developing countries, an NMS is the hierarchical set of organizations that maintains, disseminates, and applies traceable standards of measurement to



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Production of integrated circuits and many other high-value-added goods requires painstakingly accurate process controls and contaminant-free manufacturing environments—all of which rely on advanced measurement tools and capabilities.

enable valid comparisons of results. Accurate, reliable measurements, in turn, ensure equity in trade, facilitate interoperability of components in industry, advance academic research and support responsible government decision-making in matters that span from environmental protection to transportation safety to health care.

The NMS, which includes the national measurement institute (NIST, in the United States), calibration laboratories, accreditation services, weights and measures regulations, and other elements, is situated within—and operates in support of—the broader USMS. Drawing from and also contributing to the scientific research enterprise, this broader and more autonomous system encompasses measurement research and development as well as measurement technology suppliers and users, two broad categories with many divisions notable for both their variety and their vastly different requirements. Previous studies of national measurement capabilities—in the United States as well as in other countries—have been confined to an NMS point of view and did not assess the synergistic role of measurement in technological innovation.

Economic Imperative

A healthy, high-functioning USMS is vital to the production and service components of the national economy. Both the public and the private sector are challenged to ensure that the United States has the measurement capabilities and tools required by science and industry to accelerate innovation.

Reliable, high-performance software is a mission critical element of essential products and services that, increasingly, function as parts of larger systems. Effective software testing—done here for a facial recognition system—eliminates costly errors.



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The long-term stakes are high. Without a continually improving measurement system capable of providing timely solutions, the United States risks declines in industrial competitiveness and in the quality of life of its citizens.

This 11-sector survey of measurement-related barriers to technological innovation, along with the associated assessment of the USMS, is forward looking, intending to:

- Identify measurement infrastructure needs,
- Identify system gaps and weaknesses, and
- Engage stakeholders in the search for solutions.

Findings: Barriers to Innovation

The 11 areas examined constitute a significant portion of the U.S. economy. Categorically and collectively, the results yielded a more detailed understanding of how the USMS, as a system, is poised to respond to three widely recognized trends:

- Measurement needs of established industries are increasing in terms of complexity and in terms of required accuracy and precision over wider ranges.
- Emerging areas of great technological promise (such as nanotechnology, biotechnology, and fuel-cell technology) require not only enhancement of existing measurement capabilities but, often, entirely new types of measurements.

- In areas ranging from health care to information technology to environmental protection, there is growing recognition of the value and utility of reliable, high-quality measurements, resulting in additional demands for new or improved measurement capabilities.

At first glance, measurement needs across the sector/technology areas would seem to vary tremendously. And, indeed, readers with specific technology or industry interests are encouraged, first, to review the relevant high-level summaries of area-specific measurement needs in the main body of the report and, then, to delve into the more detailed descriptions contained in several appendices.

However, across the more than 700 measurement-related barriers to innovation, there are complementary challenges and requirements that link seemingly divergent needs. These may point the way to broadly useful solutions. For example:

- Requirements to improve process control transcend nearly all sectors, necessitating increased accuracy, precision, resolution, sensitivity, and repeatability.
- Opportunities to use sensors to detect, monitor, and control a wide variety of quantities, properties, and processes—in real time—are abundant and wide-ranging, from homeland security to manufacturing, but fully realizing them will require new measurement capabilities.
- Given that products and services increasingly are integrated or networked collections of hardware and software technologies, reliable metrics for quantifying overall system performance—such as interoperability and conformance to specifications—are critically needed by suppliers and customers alike.
- Along the path to the “next big thing”—be it nanotechnology, quantum computing, or a hydrogen-powered transportation system—are needs for new types of measurement capabilities, necessitating research in both basic measurement-science and applied measurement-technology.
 - During the discovery and exploratory phases of innovation, for example, new measurements are

Nanotechnology exemplifies the challenge in emerging technologies. It is a measurement-intensive and still largely experimental domain. Measurement solutions will open the way to deeper understanding and, ultimately, to new applications and markets.

Needs identified in this initial assessment of the USMS serve as compelling evidence that new or improved measurement capabilities are a collective requirement for leadership in innovation.

required to improve understanding and to enable comparisons and communication of research results.

- During the development phase, new measurement methods may be required to resolve questions about health and environmental impacts, which, if unanswered, could halt the innovation process.
- During the application and commercialization phases, new types of measurements may be needed to demonstrate the superiority of a new technology, to design cost-effective manufacturing processes, and to facilitate adoption of new, alternative technologies in standards, codes, and regulations.

Shared challenges, cross-cutting requirements, and the convergence of technologies and scientific fields suggest that multidisciplinary approaches often may be productive in the pursuit of successful solutions.

Conclusions: USMS as a Platform for Innovation

Is the USMS providing the national infrastructure that the nation must have to keep pace with the increasing measurement needs of a growing, rapidly changing, and technologically sophisticated economy?

Diverse and complex, the USMS has many strengths, but it also faces formidable challenges with respect to enabling, promoting, and accelerating technological innovation. This initial assessment concludes that, given the growing diversity of processes, products, and services it must support, the USMS will be challenged to function as a coherent system that responds effectively to multiplying and ever-more sophisticated measurement needs.

Measurement barriers to technological innovation identified in this assessment of only a portion of the national economy are clear and compelling. Concerted efforts by the private and public sectors likely are required to achieve timely resolution. Because of the complexity, pervasiveness, and systems nature of many of these barriers, individual organizations often cannot afford to act on their own, especially since returns on investments in measurement solutions usually are difficult to capture.



Vying in an increasingly competitive international market, the \$120 billion U.S. automotive industry requires new measurement tools to increase productivity, improve energy efficiency, and develop and transition to new technologies.

Collectively, research organizations that are part of the USMS will be challenged to prioritize needs within a growing inventory of measurement-related obstacles to technological innovation.

Technology roadmaps and case studies reviewed during this assessment indicate that industry often agrees on shared measurement needs. Therefore, precompetitive, collaborative research and development (R&D) is likely to be an effective vehicle for addressing needs for new measurement technologies, many of which will have broad utility.

As a core element of the nation’s technical infrastructure, the NMS component of the USMS also must evolve in concert with the international measurement system. Effective international linkages are essential to ensure that U.S.-developed technologies can meet the growing number of measurement-based standards and regulations that influence access to international markets.

Next Steps

The USMS assessment is a beginning, not an end product. It recommends steps toward resolving system-level weaknesses and enhancing USMS capabilities, with the ultimate aim of accelerating technological innovation. NIST intends to facilitate these follow-up actions, which include:

- Prioritizing measurement needs—within and across sectors;

Biomedical imaging was among the sample of broad technology areas surveyed for measurement needs. Measurement advances will enable innovative imaging technologies to deliver definitive, quantitative information for diagnostic and therapeutic purposes.



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- Creating partnerships among public- and private-sector stakeholders to focus attention and action on the most significant measurement barriers to innovation and on opportunities for synergy across industries and research areas; and
- Fostering strategic public-sector investments in measurement R&D to accelerate technological innovation.

NIST will use this assessment to focus its own work in support of U.S. innovation and competitiveness. The report's results and findings, along with input gathered in follow-up activities, will inform NIST's strategic planning decisions.

In addition, the Institute will use the assessment to cultivate broader awareness of the national importance of a robust, forward-looking measurement infrastructure as a critical, foundational element of technological innovation. This will include promoting efforts to identify and prioritize measurement needs that limit innovation and competitiveness in areas beyond the scope of this initial assessment. NIST will encourage industry groups and their university and government partners to explicitly address measurement-related barriers to innovation in technology roadmapping activities.

Feedback on this assessment from stakeholders in industry, academia, and government will be solicited and used to guide follow-up efforts.

For the complete report,
An Assessment of the United States Measurement System: Addressing Measurement Barriers to Accelerate Innovation, please go to usms.nist.gov

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